NPS-MR-06-002

NAVAL POSTGRADUATE SCHOOL

Monterey, California

Report on TNT 05-4 Atmospheric Effects Support

by

Peter Guest
Kenneth Davidson
Jeffrey Knorr
Karl Gutekunst
Richard Lind
Paul Frederickson

28 November 2005

Approved for public release; distribution is unlimited.
Prepared for: NPS Center for Defense Technology and Education for the Military Services (CDTEMS)

NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

RDML Richard H. Wells, USN
President

Richard Elster
Provost

This report was prepared for and funded by the NPS CDTEMS in conjunction with the USSOCOM-NPS Cooperative Field Experimentation Program.

Peter S. Guest
Associate Research
Professor of Meteorology

Kenneth L. Davidson
Professor of Meteorology

Jeffrey B. Knorr
Professor of Electrical and
Computer Engineering

Richard J. Lind
Meteorologist

N. Karl Gutekunst
Electronics Engineer

Paul A. Frederickson
Research Associate

Reviewed by:

Philip A. Durkee
Chairman
Department of Meteorology

Released by:

Leonard A. Ferrari, Ph.D.
Associate Provost and
Dean of Research

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** November 2005	**3. REPORT TYPE AND DATES COVERED** Technical Report	
4. TITLE AND SUBTITLE: **Report on TNT 05-3 Atmospheric Effects Support**			**5. FUNDING NUMBERS**
6. AUTHORS Peter Guest, Kenneth Davidson, Jeffrey Knorr, Richard Lind and Karl Gutekunst			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Meteorology, Naval Postgraduate School, Monterey, CA 93943-5114; Department of Electrical and Computer Engineering, Naval Postgraduate School, Monterey, CA 93943-5207			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) NPS Center for Defense Technology and Education for the Military Services (CDTEMS), Monterey CA 93943			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT

The purpose of the atmospheric effects support efforts during Tactical Network Topology (TNT) 05-4 project was to provide environmental situational awareness in a battlefield simulation. In particular, we quantified the effects of the atmosphere on radar and visual detection ranges. In an actual battlefield situation, this information would be used by forces in the field and command centers to assess the situational awareness capabilities of both friendly and enemy forces. This report discusses the efforts and accomplishments that were made to achieve this goal. All of the planned measurements, data transmission systems, real-time modeling and displays operated successfully for both of the TNT05-4 phases. The optical model predictions were significantly better than the previous TNT project. This is not surprising for the optical range predictions because modifications were made to the model based on the previous comparison results. The radar range predictions were also more accurate, even though the same models were used. The real time atmospheric effects guidance provided during TNT05-04 were accurate and valuable products suitable for use in special forces operations.

14. SUBJECT TERMS radar, optical systems, atmospheric effects			**15. NUMBER OF PAGES**: 24
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** Same as report

TABLE OF CONTENTS

REPORT ON TNT05-4 ATMOSPHERIC EFFECTS SUPPORT

A. INTRODUCTION

The purpose of the atmospheric effects support efforts during TNT 05-4 was to provide environmental situational awareness in a battlefield simulation. In particular, we quantified the effects of the atmosphere on radar and visual detection ranges. This information was made available in real time based on atmospheric measurements on the shore and on vessels in the Monterey Bay. In an actual battlefield situation, this information would be used by forces in the field and command centers to assess the situational awareness capabilities of both friendly and enemy forces. This report discusses the efforts and accomplishments that were made to achieve this goal.

We provided atmospheric effects support for two different operational phases. On 18 August, 2005, *R/V Cypress Sea* was the focus of the project while on 7 September, 2005 the *R/V Point Sur,* a larger vessel, was used. During both phases, we deployed a visual target on the research vessels and at the Rapid Environmental Assessment Laboratory (REAL) beach lab facility. For the second phase, the *Point Sur* was tracked with an ANS/SPS-67 radar from the roof on Spanagel hall on the Naval Postgraduate School (NPS) campus.

B. ATMOSPHERIC MEASUREMENTS

1. Motivation

In order to quantify radar, communication and optical detection ranges knowledge of atmospheric conditions is crucial. To support this goal, NPS personnel deployed sensor suites, on the research vessels *Cypress Sea* and *Point Sur*, and another at the Del Monte Beach site located near the NPS REAL site.

We designed this measurement program to simulate the basic near-surface atmospheric information that would be available in an operational situation. This includes wind vector, air temperature, humidity at a single level and surface temperature. Typically, how these parameters vary near the surface (which can have large effects on radar, communication and optical/IR systems) is modeled from single level

measurements. At the REAL site on Del Monte Beach in Monterey CA, we also measured air temperature and humidity at two additional levels in the air and temperature at two subsurface levels.

2. Vessel Measurements

The instruments and software used on board the *Cypress Sea* on 18 August were virtually identical to the previous TNT project (TNT05-3); the reader is referred to the previous report (in the atmospheric support section) for details and a photograph of the sensor suite. We deployed the same tower above the bridge of the *Point Sur* from 6-8 September (Figure 1), but the focus here will be on 7 September.

Figure 1. Photographs of the atmospheric sensor suite on the Point Sur from 6-8 September, 2005 during TNT 05-4.

Table 1 summarizes the instruments types and mounting heights for these sensors.

Table 1. METOC Measurements on the *Cypress Sea* and *Point Sur*.

Parameter	Height above water		Instrument	Manufacturer	Model
	Cypress Sea	*Point Sur*			
Air Temperature	3.8 m	13.6 m	Forced Aspirated Sensors	Rotronic	1/10 DIN Pt100 RTD/Hydroclip S3
Relative Humidity	3.8 m	13.6 m			
Wind Speed	4.0 m	13.8 m	Sonic Anemometer	Climatronics	Sonimometer
Wind Direction	4.0 m	13.8 m			
Pressure	2.4 m	12.2 m	Barometer	AIR	AIR-DB-1A
Sea Surface Temperature	3.7 m*	13.5m*	IR Thermometer	Apogee	IRTS-P
Ship Location/Speed	2.4 m	12.2 m	GPS Receiver	Garmin	GPS16-HVPS
Ship Heading	4.0 m	13.8 m	Compass	PNI	

*Measures temperature at surface.

One second sampled meteorological data from *Cypress Sea* and *Point Sur* were relayed to a base station at the REAL using a pair of Freewave Model FGR-115RC, 902-928 MHz, spread spectrum transceivers and 6 dB omni-directional antennae. All vessel data collection and data transfer systems were successful for both phases of TNT05-04. One minor problem was that the aspiration on the temperature/humidity sensor did not function on the Point Sur deployment, but due to natural aspiration from brisk winds, we do not believe the quality of these measurements was significantly affected.

3. Shore Measurements

We deployed a system at the REAL lab that was very similar to the previous TNT project (TNT05-03); please refer to that report for details and photographs of this system (Table 2). All of the measurements were successful for both phases of TNT05-04.

Table 2. METOC Measurements at Del Monte Beach REAL site

Parameter	Height above ground[1]	Instrument	Manufacturer	Model
Air Temperature	2.0, 1.0, 0.5 m	Forced Aspirated Sensors[2]	Rotronic	1/10 DIN Pt100 RTD/Hydroclip S3
Relative Humidity	2.0, 1.0, 0.5 m			
Wind Speed	4.1 m	Propeller Vane Anemometer	R. M. Young	05103
Wind Direction	4.1 m			
Pressure	1.5 m	Barometer	Vaisala	PTB101B
Surface Temperature	0.0 m	IR Thermometer	Everest	Model 3800ZL
Sub-surface Temperature	-0.02 m	Thermistor	Campbell Sci.	CS108
Sub-surface Temperature	-0.05 m	Thermistor	Campbell Sci.	CS107

[1]Ground level was approximately 6 meters above sea level.
[2]One sensor for each level (three sensors deployed),

C. REAL-TIME RADAR PREDICTION SUPPORT AND VERIFICATION

1. Introduction

There were two aspects of the radar prediction support provided by the atmospheric effects group during the TNT05-04 project. The first aspect was the graphical information that was provided to the tactical operations center (TOC) and other users in real time and the second aspect was a verification of the model used for this support. The following subsections describe the support that was provided, followed by several subsections about the model verifications.

2. Real Time Support

The atmospheric effects group provided predicted radar detection ranges for the *Point Sur* to all simulated field and command personnel throughout the TNT05-04 project, using the Advanced Propagation Model (APM). We provided a horizontal radar coverage diagram and a time series of radar range every 5 minutes using the atmospheric measurements described above. This information was processed at the REAL lab and then transferred over the internet for use by all interested parties, including the TOC located in Spanagel hall. In an actual battlefield situation, this information would be made available to remote command personnel as well as forces in the field using secure links. Refer to the atmospheric support section of the previous report (TNT05-03) for examples of the graphical information that was produced in real time.

3. Ship Procedure for Radar Verification Study

The radar verification study was performed on 7 September, 2005, using the *Point Sur* as a target. The *Point Sur* transited from Moss Landing to approximately 0.5 nmi off REAL lab. Upon completion of the ARIES run at 1116 PDT, the ship proceeded on an outbound heading of 335 degrees for the outbound radar run. The radar technician (Paul Buczynski) had some difficulty identifying the *Point Sur* on the radar screen initially, but once identified, he was able to track the ship out to a range of 21.3 nmi, almost to Santa Cruz on the other side of the Monterey Bay at 1352 PDT. Because the radar lab was closing at 1400 and the *Point Sur* was at the only location in the Monterey Bay that was clear and hence suitable for establishing a wireless link with the Pelican aircraft, the decision was made to forego the inbound radar run so that the ship could remain in the clear skies and obtain wireless link with the Pelican and still make it back to port by 1600 PDT. Seas were 3-4 feet during this exercise. Mr. Buczynski recorded the radar screen using a video camera which was later used to determine if the Point Sur was detected or not detected on each scan (potentially, 75 hits per scan).

4. Radar Technical Details

Personnel from the Department of Electrical and Computer Engineering at NPS (Jeff Knorr and Paul Buczynski) operated an ANS/SPS-67 radar from Radar Laboratory in Spanagel Hall on the NPS campus from 1130 PDT to 1355 PDT on 7 September, 2005. During this project the radar operated with these parameters:

Type: Simple Pulsed with PPI video integration
Frequency: 5578 MHz
Peak Power: 200 kW
Pulse Length: 0.3 microsecond
Pulse Rate: 1201 Hz
Receiver Noise: 8.7 dB
Antenna Type: Parabolic Section
Polarization: Horizontal
Antenna Gain (Relative to an isotropic antenna): 30 dBi
Scan Rate: 15 RPM
Azimuth Beam Width: 1.5 degrees
Elevation Beam Width: 16 degrees
Antenna Beam Shape: Fan beam, 0 - 16 degrees above horizon
Antenna Height: 148 feet
MDS: -94 dBm

5. Comparison of Radar Detection with Model Prediction

The radar probability of detection was modeled using the Advanced Refractive Effects Prediction System (AREPS) Version 3.04 and also using a simple analytical expression. AREPS is a user-friendly software interface which, among other things, incorporates the radar detection predictions of the APM model used for the real-time support described above. The AREPS system requires input information on the radar system, the target and the atmosphere. The radar system technical information from subsection 2 was used as input into the AREPS software. The target was the *Point Sur,* as viewed from the stern. A critical target parameter for the radar prediction model is the radar cross section (RCS). This is difficult to determine precisely, but based on typical values for similar ships and the geometry of the *Point Sur* (which has several surfaces and right angle metal features), we estimated that the radar cross section was 1000 m^2. Note that this is a much larger cross section than the *Cypress Sea* value of 14 m^2 determined by Knorr using signal substitution in the previous TNT project, the latter being a much smaller vessel than the *Point Sur*. The other critical target parameter required by the AREPS program is the target elevation. In reality, the radar reflections occur at several elevations from a ship, but the model requires that just a single elevation be specified The highest objects on the ship are on the crow's nest 19 meters above the surface. However, the main ship structures that would provide the strongest radar reflective surfaces are located below 10 meters elevation. We chose a value of 5 meters for the target elevation, representing the average height of the major ship super-structures and hull. The meteorological sensors on board the *Point Sur* were used to estimate the conditions along the radar path.

We used the video recording from the radar output screen in the radar lab in Spanagel Hall at NPS to compute a probability of detection for each one minute time interval. The radar made 15 sweeps every minute. The *Point Sur* could be identified as a white dot or short streak on the radar screen. Any sweep that indicated any type of return from the *Point Sur* was counted as a detection. The observed probability of detection was defined as the number of detections divided by the number of sweeps each minute (P_d =

m/n where *m* = number of detections and *n* = number of sweeps). For example, if there were 5 detections during a particular minute, the observed probability of detection would be $P_d = 5/15 = 0.33$. We then used the average location of the ship during that minute to relate the observed probability of detection with a radar range.

A comparison of the observed probability of detection vs. the model predicted value shows a good agreement (Figure 2). It should be noted that the model results were quite sensitive to the specified target height and the target height value of 5 m gave the best comparison. In an operational situation, both target height and radar cross section may not be accurately known and the model predictions may not agree as well with the actual results as in this case.

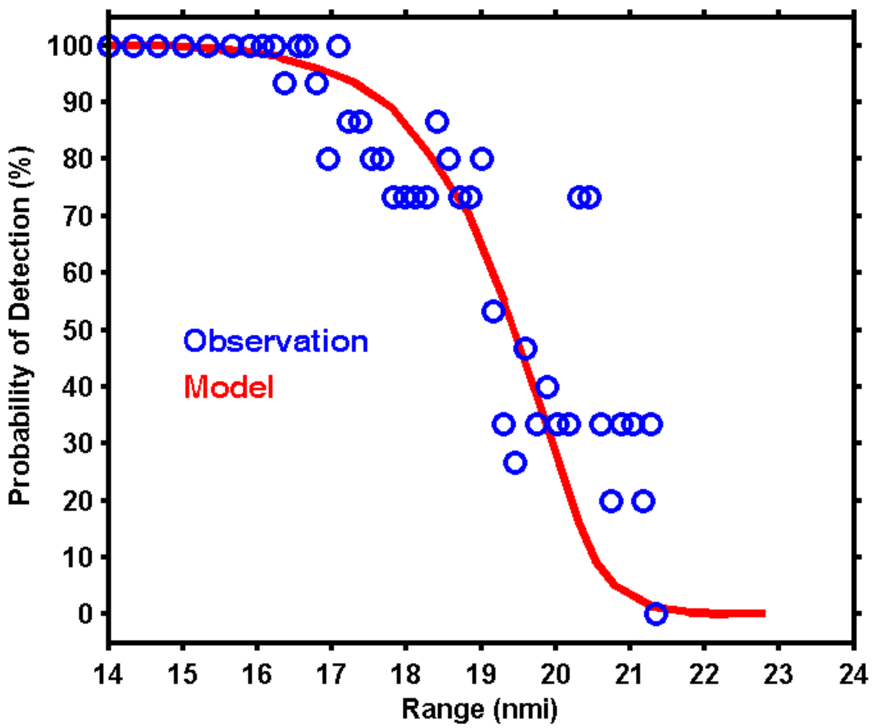

Figure 2. Comparison of observed radar detection probability vs. AREPS model predictions using the *Point Sur* as a target on 7 September, 2005.

Often, for the purpose of predicting radar range, a "standard atmosphere" is assumed. A standard atmosphere represents average conditions in the United States and assumes a constant change in height of temperature and humidity in the troposphere. But in reality temperature and humidity profiles vary depending on the meteorological

situation and this can have significant effects on radar detection ranges. For the 7 September case, a relatively weak evaporation duct was present in the lowest 3.5 meters above the ocean surface and for a few meters above this there were downward bending refractive conditions. This feature is caused by evaporation from the ocean surface and results in greatly extended ranges if the radar and target are within the duct and the radar is at a high enough frequency to be "trapped". In this case, the radar was above the evaporation duct, so one might not expect significant effects on the radar propagation. However, the AREPS range predictions using the actual measured atmospheric conditions (results shown in Figure 2) were 2 nmi greater than the range predictions using a standard atmosphere. In other words, if a standard atmosphere had been assumed, the red line in Figure 2 would be moved significantly to the left and the comparison with the actual radar data would not have been nearly as close. This demonstrates the importance of having *in situ* atmospheric measurements for getting accurate radar ranges, even if the radar is above the atmospheric ducting feature.

The measured modified refractivity profile for the period of the radar detection experiment with the *Point Sur* (Figure 3), shows the standard atmosphere conditions

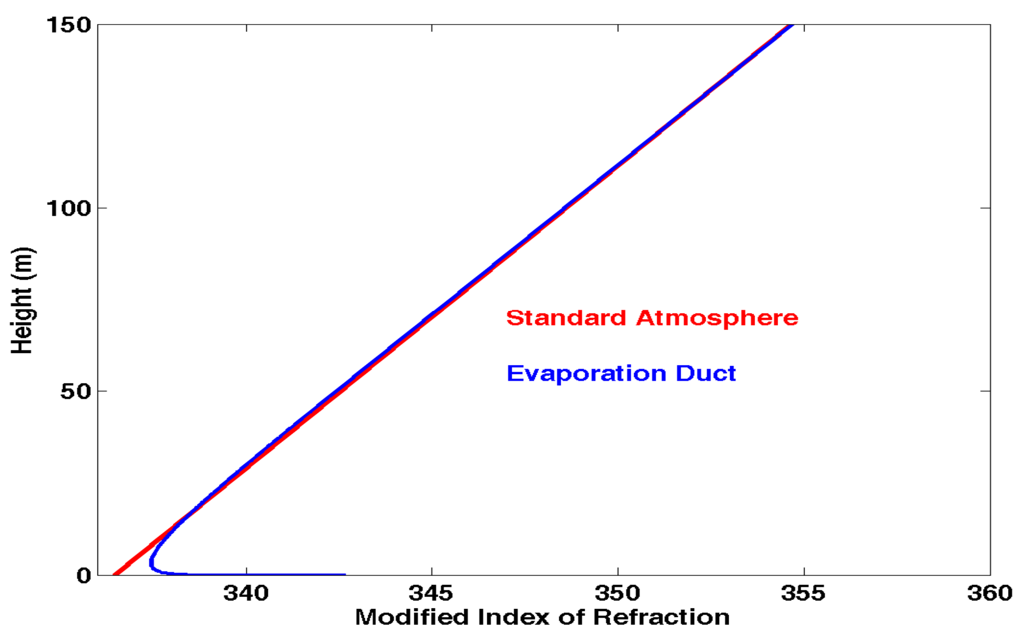

Figure 3. Measured modified refractivity profile for the period of the radar detection experiment with the *Point Sur* on 7 September 2005, based on the measurements from the ship (evaporation duct), compared to a standard atmosphere.

(118 M-units/km) that were assumed to exist in the range from 20-150 meters where most of the propagation path lies. Practically, when range exceeds the sum of the horizon distances for the radar and the target, smooth earth diffraction will introduce additional propagation loss. At the C-band frequencies of the radar, this diffraction loss will increase significantly as range exceeds the sum of the two horizon distances and detection probability will rapidly decrease. Analytically, the maximum detection range in a standard atmosphere can be calculated approximately as the sum of horizon distances,

$$R_{\max} = 0.85 \times \left[\sqrt{2h_a} + \sqrt{2h_t} \right]$$

where

$R_{\max} =$ max. detection range in nmi.

$h_a =$ radar antenna height in ft.

$h_t =$ target height in ft.

Using h_a = 148 ft. and h_t = 16.25 ft (5 meters), the equation above leads to a maximum detection range,

$$R_{\max} = 14.6 + 4.8 = 19.4 \text{ nmi.}$$

This detection range is very close to the range at which the observed detection probability is $P_d = 0.5$. Thus, the analytically determined maximum detection range is in good agreement with the ranges determined from both measurement and computer prediction. The analytical model also illustrates the sensitivity of the maximum detection range to the height assumed for the ship target.

D. REAL-TIME VISUAL DETECTION SUPPORT AND VERIFICATION

1. Introduction

Target visibility from the human eye or optical and infrared (IR) sensors is a concern for various operations. Target visibility can be affected by sun angle, target and background characteristics, the atmospheric aerosol (particles) and optical turbulence. For TNT05-4 the atmospheric effects group used a model that included the effect of optical turbulence, aerosol and visual acuity of the human eye. During the two phases of

TNT05-4, optical range was estimated by observation of standardized targets. Standardized targets were placed on shore for viewing from the ship (as in previous TNTs) and also on the vessels *Cypress Sea* (18 August) and *Point Sur* (7 September). The latter targets were a new addition to what was done previously and allowed comparison of visibility along the same optical path, but in different directions. Details and photographs of the standard targets are contained in the previous (TNT05-3) report.

2. Optical Model

Optical turbulence causes a target to become less distinct and move about in a random pattern. This phenomenon is familiar to most people who have observed the "twinkling" of a star. This twinkling is a manifestation of optical turbulence. Optical turbulence is quantified by a parameter called the refractive structure function, or C_N^2. Higher C_N^2 means that the targets maximum resolution range will be less. The refractive structure function was determined using the real time atmospheric measurements. (The data from these measurements are not shown here, but plots are available from the authors upon request.) The details on how C_N^2 was calculated are beyond the scope of this report, but can be obtained from the authors of this section.

Aerosol affects visibility by scattering and absorbing light. During the 18 August phase of TNT 05-4, aerosol concentrations were relatively low and did not have a significant effect on visibility in the ranges that were used. However, during the 7 September phase, aerosol concentrations were higher, causing haze and limiting the visibility to 3-5 nmi. This was especially important for the binocular observations, where larger ranges are more affected by the aerosol.

For the previous TNT, we assumed that the naked human eye for a person with 20/20 vision can resolve objects at a distance 5800 times the size of the object. This requires a sharp contrast of the target and background and perfect viewing conditions. However, based on the results of the previous TNT, we decided to use a human eye resolution of only one half of this value or 2900 times the size of the object.

Using a telescope or binoculars increases an individual's visual acuity. The amount of improvement increases linearly with the magnification of the instrument, but there is some instrument degradation because the lenses can never be perfect, some light

is absorbed and there are reflections and other effects that cause instrument degradation. For this project we used 7 power binoculars and assumed that the instrument degradation was 30%. Optical instruments only improve an individual's visual acuity, they do not provide any improvement for optical turbulence or aerosol effects.

As before, the three effects of optical turbulence, aerosol and visual acuity were combined in a least-squares sense to give the final overall predicted visual range for various targets.

3. Optical Range Predictions

In support of the TNT 05-3 activities, the atmospheric effects group used the optical model described above to predict the ranges at which various size standard targets could be visually detected with the naked eye and with binoculars. In order to have a standardized measure of visibility, a target was set up at the REAL lab location on the shoreline (see previous report for a photograph). It consisted of three series of black and white lines of varying sizes. These predictions were displayed graphically and were available at the TOC command center throughout the project (Figure 4). For the 18 August phase, these predictions are based on the atmospheric measurements from the *Cypress Sea.*

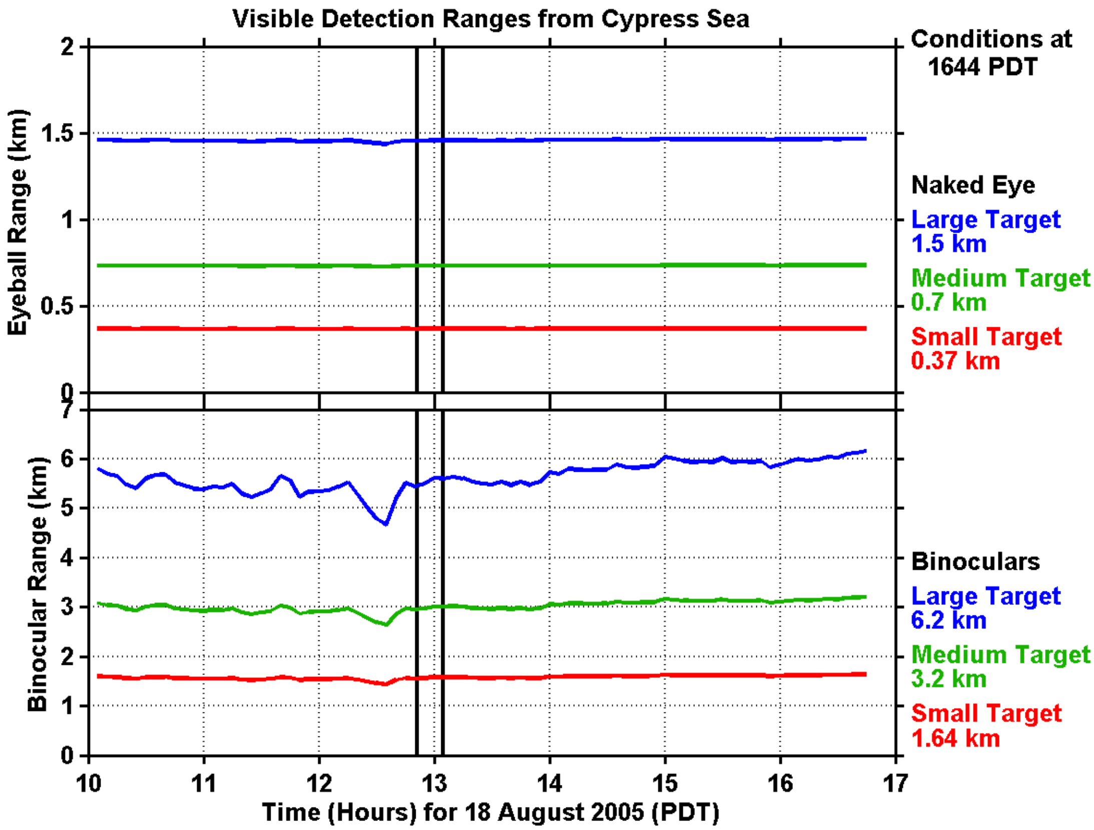

Figure 4. The visual range product that was available in real-time for TNT 05-4. These show the predictions of visibility from the *Cypress Sea* to the REAL beach lab site on 18 August. These are based on the meteorological data and the optical model described in this section. The top plot represents ranges with the naked eye while the bottom plot represents ranges with 7 power binoculars. Note that the vertical scale is different for the two plots. The blue lines represent the predicted visual ranges for the large target (20 inch bar cycle), green lines are for the medium target (10 inch bar cycle) and the red lines is for the small target (5 inch bar cycle). The two vertical black lines bracket the period during which actual observations of range were undertaken; these were not shown in the real-time product. The information on the right provides data on the latest predictions for operational use. The information represents the last points on the plots, which in this case are 1644 PDT 18 August, 2005.

For the 18 August phase, a small target (5 inch bar cycle) was mounted on the mast of *Cypress Sea* and atmospheric data from the REAL site was used as input into the optical range prediction model (Figure 5).

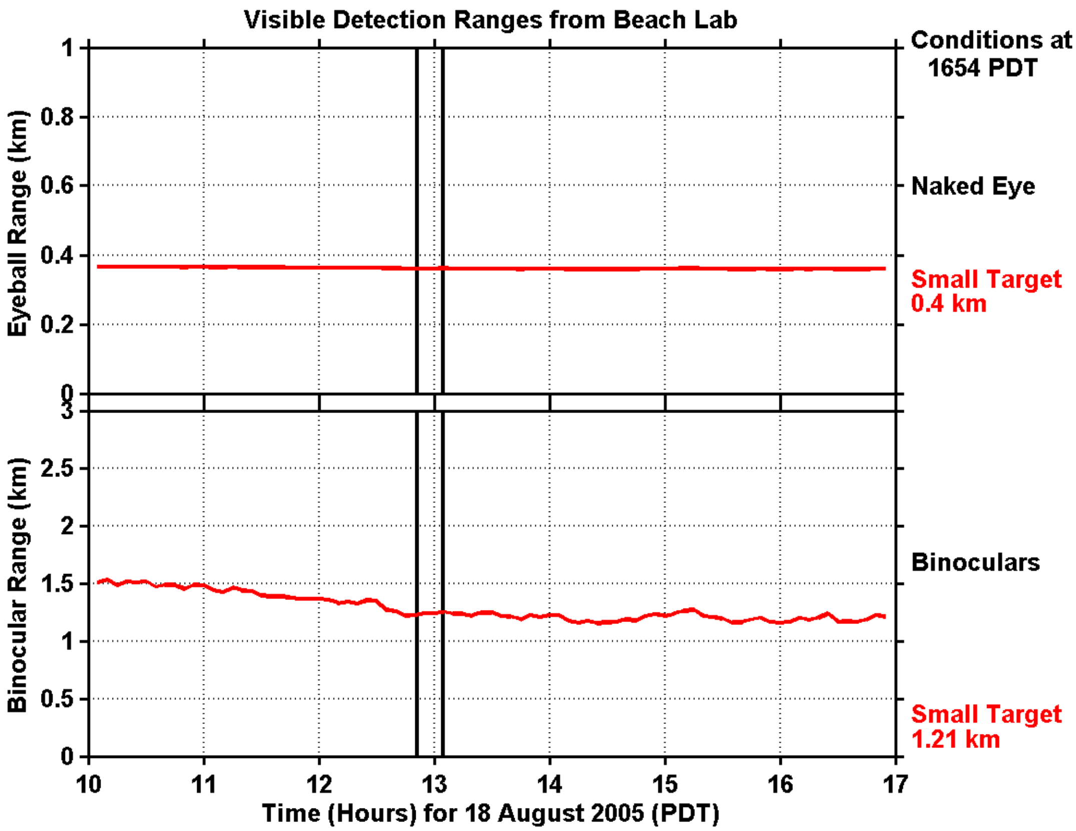

Figure 5. Same as Figure 4 but for the beach-to-ship view. Only the small target was on the ship.

For the 7 September phase, a similar procedure was followed, except the *Point Sur* was used as the vessel instead of the *Cypress Sea* (Figure 6). The shipboard person observed all three shore targets from the main deck of *Point Sur* which is roughly the same height as the *Cypress Sea*. This provided consistent data with that obtained during visualization runs on-board the *Cypress Sea*.

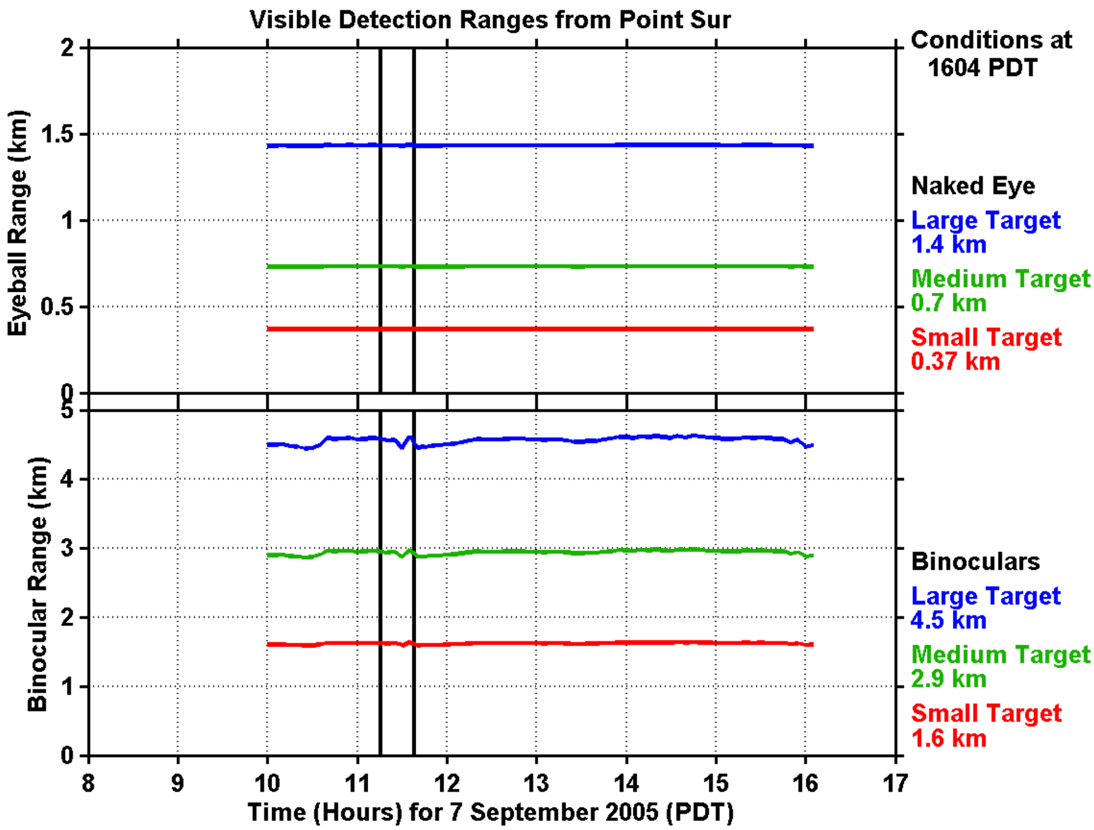

Figure 6. Same as Figure 4 but for the 7 September phase. Note that the predicted range for the large target was less for this phase than the 18 August phase. This is because there was haze present and this was accounted for in the aerosol part of the optical range prediction model.

For the 7 September phase, a small target was affixed to the *Point Sur* bridge railing and a medium target (10 inch cycle) was affixed to the railing on the roof above the bridge. Atmospheric data from the REAL site was used as input into the optical range prediction model (Figure 7).

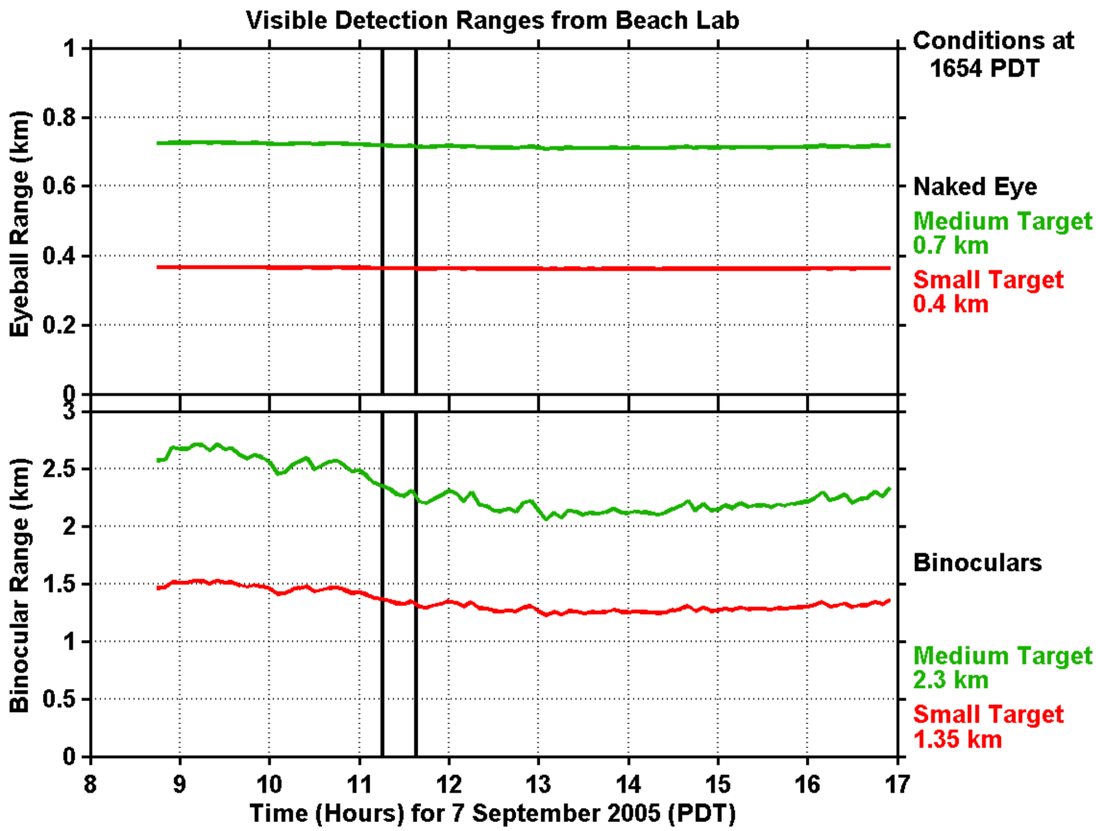

Figure 7. Same as Figure 6 but for the beach-to-ship view. Only the small and medium targets were on the ship.

The variations in the lines for Figures 4-7 are a result of the changing atmospheric conditions. Notice that at close distances, such as the predicted range for the small target as seen with the naked eye, there is no temporal variation. This is because at these distances, the optical turbulence has an insignificant effect, and the range is entirely determined by the observer's visual acuity. In contrast at greater distances, such as the

range for the large target with binoculars, the atmosphere has a greater effect and there are temporal variations as atmospheric conditions change.

4. Comparison of Optical Range Predictions with Actual Observations

From 1951 PDT to 2006 PDT on 18 August, 2005 the *Cypress Sea* approached the REAL beach site while an onboard observer recorded the times when he could distinguish the different lines on the targets. At the same time, a beach observer determined when he could distinguish the lines on the small target on the vessel. During this period, there was broken overcast sky and good visibility. Seas were calm. There was no communication between the ship and shore observers during this time.

A similar procedure was followed from 1116 PDT to 1139 PDT on 7 September, 2005. In this case the ship was the *Point Sur* and it was moving away from the beach. The *Point Sur* had small and medium targets. Skies were overcast with a ceiling at approximately 700 ft. Haze and fog reduced visibility to 3-5 nmi. The times when the various targets were resolved were related to a range from the vessel to the target using the ship GPS. This was done after the actual field program.

The model results were not tuned in any way during or after the observations were made. There were some changes to the model done prior to the experiment, as described subsection 3 above. In order to have more data for comparison, the prediction model was re-run for the May TNT5-03 case using the changes that were developed. The results from TNT5-03 and both phases of TNT05-04 are summarized in Table 3 and Figure 8. Observation data were not available for all possible target sizes and paths.

As can be seen, the model slightly over-predicted the maximum ranges at which the targets would be resolved, in most cases. In other words the observer could not see the objects quite as well as predicted. However due to the changes in the model, the prediction were much more accurate than as described in the previous report. The binocular predictions were somewhat less accurate (too far) in the relative and absolute sense than the naked eyeball predictions. It may be that the optical degradation of the binoculars should have been greater than the 33% that was assumed for the model.

Table 3. Predicted and Actual Visible Resolution Ranges*

Target	Binoculars (6X Power)			Naked Eye (20/20 Vision)		
	Time (PDT)	Observed Range	Predicted Range	Time (PDT)	Observed Range	Predicted Range
Large Lines[1]	1618:00 1138:20	3.907 3.394	4.854 4.509	1625:00 1301:00 1127:00	1.304 0.976 1.322	1.437 1.454 1.432
Medium Lines[2]	1624:10 1255:35 1129:15 1128:45	1.617 1.675 1.916 1.777	2.668 2.962 2.902 2.267	1626:45 1303:10 1119:00	0.669 0.598 0.716	0.737 0.732 0.720
Small Lines[3]	1626:00 1301:08 1258:30 1119:00	0.940 0.953 1.417 0.839	1.511 1.537 1.227 1.334	1629:30 1304:54 1304:25	0.312 0.316 0.374	0.412 0.368 0.362

*Black numbers are for the TNT5-03 May case which was a ship-to-shore path.
Red numbers are for the 18 August ship-to-shore path.
Green numbers are for the 18 August shore-to-ship path.
Magenta numbers are for the 7 September ship-to-shore path.
Blue numbers are for the 7 September shore-to-ship path.
[1]Standard Target, bar cycle = 20 inches
[2]Standard Target, bar cycle = 10 inches
[3]Standard Target, bar cycle = 5 inches

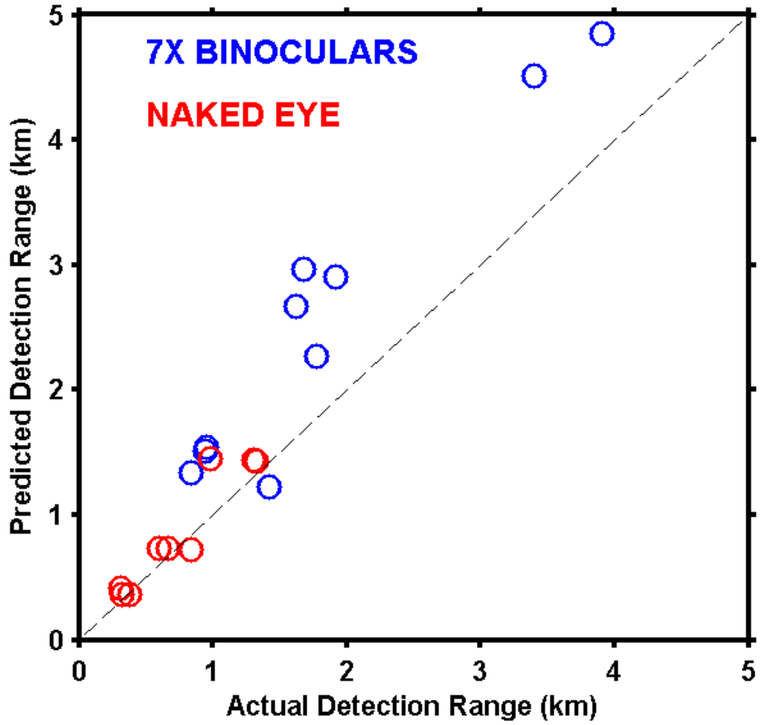

Figure 8. A graphical representation of the same data shown in Table 3. The dashed line represents where the points would fall if the model and observed data matched perfectly. Note the colors of the points do not represent the same characteristics as the color of the numbers in Table 3.

Because the warming of the surface near the shore causes more optical turbulence, the model predicted slightly degraded ranges for the shore-to-ship paths as compared to the other way around. However, the actual observations showed that in all cases when the same type of target was observed, the ship observer actually resolved the targets at further ranges. The reason for this is not certain, but it may be because the ship observer (Karl Gutekunst) had performed the same task in the earlier TNT and hence had more experience at making observations than the shore observer (Terrence Beltz) who was doing it for the first time. Or perhaps the former has better vision.

E. ATMOSPHERIC EFFECTS SUPPORT: SUMMARY AND CONCLUSIONS

1. System Performance

All of the planned measurements, data transmission systems, real-time modeling and displays operated successfully for both of the TNT05-4 phases. This demonstrates that providing special operations personnel with information on radar, communications and target detection ranges in real time is feasible, as long as basic information (temperature, humidity, wind speed) is available near the surface in the area of operations.

2. Model Prediction Accuracy

The optical model predictions were significantly better than the previous TNT project. This is not surprising for the optical range predictions because modifications were made to the model based on the previous comparison results. The radar range predictions were also more accurate, even though the same models were used. This may be due to a more accurate radar cross section specification. Another reason may be because a larger ship was used for the target, thus making it less affected by changes in radar reflection due to ship motion from swell.

3. Concluding Remarks

We believe that the real time atmospheric effects guidance provided during TNT05-04 were accurate and valuable products suitable for use in special forces operations. There is still a need for further refinement and testing under different conditions. Therefore we recommend that comparisons of radar and visibility range between predictions and actual measurements be continued in future TNT projects. The atmospheric effects group will continue to leverage our work for TNT by developing our measurement and modeling capability outside of the TNT framework. One opportunity will come during an educational student cruise of the *Point Sur* in January. We will encourage students to perform research on how to best serve our special forces in providing guidance products for radar and optical range nowcasts and predictions.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center — 2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library, Code 013 — 2
   Naval Postgraduate School
   Monterey, CA 93943-5100